Effects of Cigarette Smoking on Endurance Performance Levels of 16- to 19-year-old Males

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Abstract

The purpose of this study was to explore the effects of cigarette smoking on the levels of endurance performance in teenagers. Longitudinal data of physical characteristics, smoking habits, exercise habits, and time records in both 1500-meter run and 10-kilometer run of 202 sixteen-to-nineteen-year-old male students were retrieved and analyzed retrospectively. The results showed that the performance levels of exercise-neversmokers in the 1500-meter run did improve as the subjects grew older, and that over the same period, the exercise-smokers did not improve but were able only to maintain their performance levels. The results of two way analysis of variance(ANOVA) indicated that smoking negatively and independently impacts how eighteen and nineteen-year-olds will perform in a 10-kilometer run. The reduced levels of endurance performance in the non-exercise smokers showed up in their results in the 10-kilometer run, and the diminished performance levels of the exercise-smokers were revealed in their 1500-meter run times. These results suggest that smokers obtain less benefits from training than non-smokers, and that we need to assess endurance performance levels among the young by paying careful attention to their smoking habits.

Key words: cigarette smoking, physical fitness, exercise habit, young male student, endurance performance

Introduction

The physiological effects of nicotine, tar and carbon monoxide on the respiratory and cardiovascular systems of adults have been well studied¹⁻³⁾. In contrast, the effects of cigarette smoking on the endurance performance of teenagers who are just beginning to smoke have not been well documented^{4,5)}. Incidentally, the endurance performance of Japanese teenagers has recently been observed to be generally deteriorating, rather than increasing⁶⁾. We presume that one of the reasons for this phenomenon is the possible detrimental effects of smoking. A longitudinal study of what happens when a subject does or does not combine smoking with the process of physical training may help to answer the question of whether smoking does or does not alter the effects of physical training⁷⁾.

The purpose of the present study was to analyze longitudinal data acquired through a retrospective study of sixteen-to-

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nineteen-year-olds to explore how cigarette smoking affected their endurance performance.

Methods

Subjects

The subjects were 307 male students, 140 males (19years of age) and 167 males (20years of age) respectively, enrolled in March 1995 for their fourth and fifth year at the F. National College of Technology in Japan. The school has five grades and each is comprised of 200 students of both sexes. Students turn 16 years of age during the first year and 20 during the fifth year. In this study subjects from 2 grades were used. Sixteen-year-old subjects, for example, were drawn from both groups. A total of 167 males entered the school in April 1990 and, 140 males in April 1991. Forty one of the original 307 subjects did not have the longitudinal endurance performance records for the 1500meter run (1500MR) and 72 subjects of 307 did not have the longitudinal endurance performance records for the 10-kilometer run (10KMR) during their sixteen-to-nineteen-year-olds. Thus, longitudinal endurance performance records for both the 1500MR and the 10KMR were available for 222 of the original 307 sixteen-to-nineteen-year-olds. Nine of the 222 in 1500MR records and eleven of the 222 in 10KMR records were rejected because the times (within the respective age category) exceeded the value of mean + 3SD. The rejected 20 records was considered as the results of the endurance performance records combined with walking. The longitudinal data of the remaining 202 male students were therefore analyzed. The participants in the 10KMR had no history of heart disease and they had normal blood pressure. The nature and aims of the study were explained to all subjects who consented to take part. This study was performed with the permission of the school administration.

Questionnaire About Smoking Habits

Subjects were asked to respond to items on a questionnaire which was administered in March 1995. By recalling their past smoking histories, the subjects were requested to answer two questions: 1) The date they started smoking; and 2) The mean number of cigarettes per day each month since starting smoking to present. The second question was in the format of a sheet of paper divided into columns listing all of the months from April 1986 to March 1996. In this study, the definitions of smoking habits were as follows: 1) Smoker--a person who smoked at least one cigarette per day per month at the time of the study; 2) Neversmoker--a person who had never smoked; 3) Nonsmoker-neversmoker plus anyone who had not smoked within the previous six months. The phrase "smoking habit" was used to distinguish subjects as either smokers (an individual who had a current smoking habit), or never-smoker/ non-smokers (an individual who did not have a current smoking habit).

Physical Characteristics, Exercise Habits, and Endurance Performance

Physical characteristics were measured, and exercise habits were documented. Each year, the same group of teachers used the criteria laid out in "The Sports Tests" of the Physical Education Bureau of the Japanese Ministry of Education. The data on physical characteristics consisted of records of height(cm), weight(kg), and the sum of skinfold thickness-- triceps plus subscapular(mm). From this information, the percentage of body fat(%)8.91, and the lean body weight(kg) of each subject were calculated. Exercise habits were examined as follows: the individual 1) exercised almost every day(three or more days per week); 2) sometimes exercised(less than 3 days per week); 3) seldom exercised(less than two days per month); and 4) never exercised. In this study, "exercisers" were defined as subjects who exercised three or more days per week, and "non-exercisers" were defined as those who exercised less than 3 days per week. A 1500MR was conducted on a regular 400- meter race track every May from 1990 to 1995 as a part of the regular yearly schoolwork routine in a physical education class. A 10KMR was conducted every November as a school function and was performed on a 10km flat course located near the school campus. The levels of endurance performance results, in the form of completed race times in seconds for each subject in each race, were taken and recorded.

Statistical Analysis

The SPSS package version 4.0 was used for statistical analysis (SPSS Inc, Tokyo, Japan)¹⁰⁾. Student's t test was used to evaluate differences between the groups. Two-way analysis of variance (ANOVA) was used to evaluate the influences of smoking and exercise habits on the endurance performance. P value less than

5% was used as the criterion of significance.

Results

Smoking Habits and Exercise Habits

The numbers of smokers, non-smokers, exercisers and non-exercisers within each age category among the 202 male students are shown in Table 1. To establish the most valid system of comparison of the data collected about smoking habits, physical characteristics, exercise habits, and the results from the 1500MR and 10KMR, only data from the months of May and November included in the answer to the second item on the questionnaire on smoking habits were used. In May, the percentage of smokers in the sixteen-year-old category was 14.9%, and the mean number of cigarettes smoked per day was 10.7 cigarettes. The percentage of smokers and the mean number of cigarettes smoked per day in May within the categories of seventeen-, eighteen- and nineteen-year-olds were 27.7% and 13.1 cigarettes, 39.6% and 13.8 cigarettes, and 45.0% and 14.7 cigarettes, respectively.

Of the 202 subjects, there were 148 exercisers (73.3%) in the sixteen-year-olds, 125 exercisers (61.9%) in the seventeen-year-olds, ninety-eight exercisers (48.5%) in the eighteen-year-olds, and seventy exercisers (34.7%) in the nineteen-year-olds.

Some of the 202 subjects continued certain behavior for four years: 28 subjects who were neversmokers continued to exercise(Exercise-neversmokers); 7 subjects who were smokers continued to exercise(Exercise-smokers); 5 subjects who were smokers continued not to exercise(Nonexercise-smokers); and 18 subjects continued to be neversmokers and not exercise (Nonexercise-neversmokers). These numbers correspond to the data shown in Fig. 1.

Twenty-eight subjects had started smoking prior to the age of sixteen, 24 subjects started to smoke at seventeen, 25 subjects started at eighteen, and 13 subjects had become smokers at nineteen. These numbers correspond to the data for the sample shown in Fig. 2.

Physical Characteristics

The cumulative longitudinal changes in the physical characteristics of the 202 subjects as they went from age sixteen to nineteen, and the cross-sectional changes in regard to smoking and exercise habits that occurred from one age group to the next are shown in Table 1. Although the overall height, weight and lean body weight are increased significantly with each year (paired t-test, p<0.05), no significant difference between the weights of the eighteen and nineteen-year-olds was shown. The sums of skinfold and percentage of body fat are significantly less in the nineteen-year-olds than in the sixteen-, seventeen- and eighteenyear-olds, and these figures are also significantly less in the eighteen-year-olds than in seventeen-year-olds (paired t-test, p<.01). The means \pm SD of body fat in the sixteen-, seventeen-, eighteen- and nineteen-year-olds were 8.2 ± 3.3 kg, 8.8 ± 3.8 kg, 8.6 ± 3.5 kg, and 8.2 ± 3.1 kg, respectively. The mean values of body fat were significantly higher in the seventeen and eighteenyear-olds than in nineteen-year-olds (paired t-test, p<0.05).

Overall, no significant differences in height, weight, sums of skinfold, lean body weight, body fat and the percentage of body fat were observed between the smokers and non-smokers. However, the heights of the sixteen and nineteen-year-old smokers were significantly greater than those of the same-aged non-smokers (unpaired t-test, p<0.05).

Table 1 Longitudinal analysis of physical characteristics and 1500m and 10km run records, and cross-sectional analysis of smoking habits

Items	exercise habits for all subject Group		Age (yrs)							
		16 17 18								
Height (cm)	Total	168.3 ± 5.7	(202)	170.2 ± 5.6	(202)	170.9 ± 5.6	(202)	$\frac{19}{171.7 \pm 5.8}$	(202)	
Treight (Chi)	Smoking habits	200.5 _ 5.17	()	-, -,- = ,,-	()	-, -,, -,,,	()	-, -,, -,,,	(===)	
	Non-smokers	$168.0 \pm 5.7*$	(172)	170.2 ± 5.4	(146)	170.8 ±5.6	(122)	171.0 ±5.8*	(111)	
	Smokers	170.2 ± 5.1	(30)	170.4 ± 6.2	(56)	171.2 ± 5.8	(79)	172.6 ± 5.6	(91)	
	Exercise habits	170.2 = 3.1	(30)	170.1 = 0.2	()0)	171.2 - 7.0	(17)	172.0 = 3.0	()1)	
	Exercisers	168.6 ± 5.4	(148)	170.7 ± 5.4	(125)	171.4 ± 5.3	(98)	171.8 ± 5.6	(70)	
	Non-exercisers	168.6 ± 0.4 167.6 ± 6.4	(54)	$1/0.7 \pm 5.4$ 169.5 ± 5.9	(77)	171.4 ± 5.5 170.5 ± 6.0	(103)	171.8 ± 5.0 171.7 ± 5.9	(132)	
Waight (Ira)	Total									
Weight (kg)		57.0 ± 7.2	(202)	59.7 ± 7.3	(202)	61.2 ± 7.4	(202)	61.4 ± 7.4	(202)	
	Smoking habits	560 170	(170)	50 () 70	(1.46)	(1.2.1.7.6	(1.22)	(15 70	(1.1.1)	
	Non-smokers	56.8 ± 7.0	(172)	59.6 ±7.0	(146)	61.3 ± 7.6	(122)	61.5 ± 7.9	(111)	
	Smokers	57.7 ± 8.4	(30)	60.1 ± 8.0	(56)	61.0 ± 7.0	(79)	61.2 ± 6.8	(91)	
	Exercise habits		4- 4-5		/ - \		. >		 ->	
	Exercisers	56.9 ± 6.5	(148)	60.4 ± 6.5	(125)	62.4 ± 7.6*	(98)	61.6 ± 7.5	(70)	
	Non-exercisers	57.1 ± 9.0	(54)	58.7 ± 8.4	(77)	60.1 ± 7.0	(103)	61.3 ± 7.4	(132)	
SFT ^a (mm)	Total	20.8 ± 6.8	(199)	21.6 ± 7.6	(202)	20.4 ± 6.8	(202)	19.3 ± 6.3	(201)	
	Smoking habits									
	Non-smokers	20.9 ± 6.9	(169)	21.1 ± 7.1	(146)	20.7 ± 6.7	(122)	19.6 ± 6.3	(110)	
	Smokers	20.3 ± 6.8	(30)	22.7 ± 8.8	(56)	20.0 ± 7.0	(80)	18.8 ± 6.4	(91)	
	Exercise habits									
	Exercisers	20.4 ± 6.2	(147)	21.1 ± 6.5	(125)	20.6 ± 7.0	(98)	18.7 ± 6.8	(69)	
	Non-exercisers	21.9 ± 8.3	(52)	22.2 ± 9.1	(77)	20.2 ± 6.7	(104)	19.6 ± 6.1	(132)	
% body fat (%)	Total	14.0 ± 4.0	(199)	14.5 ± 4.6	(202)	13.8 ± 4.0	(202)	13.1 ± 3.8	(201)	
	Smoking habits									
	Non-smokers	14.1 ± 4.0	(169)	14.2 ± 4.2	(146)	14.0 ± 4.0	(122)	13.3 ± 3.8	(110)	
	Smokers	13.7 ± 4.0	(30)	15.2 ± 5.3	(56)	13.6 ± 4.2	(80)	12.8 ± 3.8	(91)	
	Exercise habits									
	Exercisers	13.8 ± 3.7	(147)	14.2 ± 3.8	(125)	14.0 ± 4.2	(98)	12.8 ± 4.0	(69)	
	Non-exercisers	14.6 ± 5.0	(52)	14.9 ± 5.51	(77)	13.7 ± 4.07	(104)	13.3 ± 3.6	(132)	
LBW ^b (kg)	Total	48.8 ± 5.0	(199)	50.9 ± 4.9	(202)	52.6 ± 5.2	(202)	53.2 ± 5.3	(201)	
	Smoking habits	-	, , ,		• /		• •		, ,	
	Non-smokers	48.7 ± 4.9	(169)	51.0 ± 4.9	(146)	52.6 ±5.5	(122)	53.2 ± 5.8	(110)	
	Smokers	49.5 ± 4.9	(30)	50.7 ± 5.1	(56)	52.6 ± 4.8	(80)	53.2 ± 4.8	(91)	
	Exercise habits	17.17 — 1.17	(55)	yu,y	(50)	72.0 = 1.0	(00))	(> -)	
	Exercisers	48.9 ± 4.6	(147)	51.7 ± 4.7**	(125)	53.5 ±5.3*	(98)	53.5 ±5.1	(69)	
	Non-exercisers	48.5 ± 5.7	(52)	49.6 ± 5.0	(77)	51.7 ± 5.0	(104)	53.0 ±5.5	(132)	
500m ^c (sec)	Total	365 ± 27.0	(202)	373 ± 33	(202)	369 ± 35	(202)	367 ± 32	(202)	
1500m° (sec)	Smoking habits	JUJ == 27.0	(202)	373 - 33	(202)	307 ± 37	(202)	307 = 32	(202)	
	· · ·	366 ± 26	(172)	372 ± 33	(146)	368 ± 37	(122)	365 ± 33	(111)	
	Non-smokers Smokers			3764 ± 34	(56)	372 ± 32	(79)	307 ± 33 371 ± 31	(91)	
		357 ± 30	(30)	3/04 ± 34	(36)	3/2 ± 32	(/ 9)	3/1 ± 31	(91)	
	Exercise habits	$360 \pm 27^{***}$ (148) $363 \pm 29^{***}$ (125) $354 \pm 32^{***}$ (98) 35						255 1 20**	*/70\	
	Exercisers			363 ± 29***				355 ± 28**		
	Non-exercisers	377 ± 22	(54)	389 ± 34	(77)	384 ± 31	(103)	374 ± 32	(132)	
10km ^d (sec)	Total	3246 ± 408	(202)	3253 ± 452	(202)	3358 ± 510	(202)	3520 ± 683	(202)	
	Smoking habits	20/0 1 /5:					22(5 ± /20***/122)		2/00 ± /1/**/111	
	Non-smokers				3216 ± 449 (146) $3265 \pm 438***$					
	Smokers	3272 ± 461	(30)	3348 ± 451	(56)	3500 ± 579	(79)	3666 ± 736	(91)	
	Exercise habits									
	Exercisers	$3134 \pm 334*$		3134 ± 394**		3159 ±403*		3357 ±613*		
	Non-exercisers	3554 ± 438	(54)	3445 ± 477	(77)	3545 ± 531	(103)	3606 ± 705	(132)	

Values are means \pm SD.

There were no significant differences in the height, weight, sums of skinfold, lean body weight, body fat or percentage of body fat between the eighteen-year-old exercisers and non-exercisers, whereas a significant difference was noted in the weights of the eighteen-year-old exercisers and non-exercisers, and the lean body weights of the seventeen and eighteen-year-old exercisers and non-exercisers. In both cases, the weight was

significantly higher in the exercisers than in the non-exercisers (unpaired t-test, p<0.05).

Changes in Endurance Performance with an Increase in Age

A longitudinal analysis of the performance in the 1500MR revealed a significant decrease in the endurance performance from 16 to 17 years of age (p<0.001). The times recorded for the

aSFT, Sum of skinfold thickness; bLBW, Lean body weight; c1500m, 1500m running records; d10km, 10km running records.

^{*}p <0.05, **p <0.01, ***p <0.001: significant difference between nonsmokers and smokers or exercisers and non-exercisers in the same age category.

eighteen-year-olds in the 1500MR were significantly longer than that for the sixteen-year-olds (p<0.05), and the times recorded for the nineteen-year-olds in the same race were significantly shorter than that for the seventeen-year-olds (p<0.001). Although the 10KMR performance levels were maintained from the sixteen to the seventeen-year-olds, the performance of the eighteen-year-olds decreased significantly compared to that of the sixteen- or seventeen-year-olds. In addition, the performance levels of the nineteen-year-olds decreased significantly compared to the levels of the sixteen-, seventeen- and eighteen-year-olds (p<0.001)(Table 1).

Relationships between Endurance Performance and Smoking Habits or Exercise Habits

In all age categories in the execution of the 1500MR, we observed no significant difference in the performance levels between non-smokers and smokers. Although there was no significant difference between the performance levels of the sixteen and seventeen-year-old non-smokers and smokers in the 10KMR, the 10KMR records of the eighteen- and nineteen-year-old smokers were significantly longer than those of the same-aged non-smokers. In both the 1500MR and the 10KMR, the race times of the non-exercisers in all age groups were significantly longer than those of the same-aged exercisers (Table 1).

ANOVA for Smoking Habits and Exercise Habits of the Endurance Performance

Table 2 shows the results of the two-way ANOVA performed to evaluate the influence of smoking and exercise habits on the levels of performance. The factor of smoking habit was found to have no main effect on the performance of the 1500MR in all age categories. However, smoking habits had a main effect on the level of performance of the eighteen and nineteen-year-olds in the 10KMR. The factor of exercise habits was shown to have a main effect on the performance levels of all age groups in both the 1500MR and 10KMR. An interaction between smoking and exercise habits was not observed.

Correlations Between Smoking Habits, Exercise Habits and Endurance Performance Levels

Figure 1 reveals the longitudinal effects that smoking habits and exercise habits had on the subjects' performance levels in the 1500MR and 10KMR. Although the performance levels of the

Table 2 ANOVA for smoking and exercise habit

Age (yr)	Source	df	F			
			1500m running record	10km running record		
16	Smoking habits (S)	1	3.13	0.18		
	Exercise habits (E)	1	17.26***	52.04***		
	$S \times E$	1	0.50	0.01		
17	Smoking habits (S)	1	0.02	1.74		
	Exercise habits (E)	1	33.30***	23.15***		
	$S \times E$	1	0.93	0.57		
18	Smoking habits (S)	1	0.07	8.84**		
	Exercise habits (E)	1	45.69***	31.44***		
	$S \times E$	1	0.40	2.53		
19	Smoking habits (S)	1	0.89	6.52*		
	Exercise habits (E)	1	17.21***	4.92*		
	$S \times E$	1	3.64	1.16		

Note: 1500m and 10km running records of each year of age are shown in Table 1. *p<0.05, **p<0.01, ***p<0.001.

exercise-neversmokers in the 1500MR did not change between the ages of sixteen and seventeen, the levels of the eighteen and nineteen-year-old exercise-neversmokers increased significantly over those of the sixteen- and seventeen-year-olds. In contrast, the performance levels of the exercise-smokers in the 1500MR did not increase, but were maintained from the age of sixteen to nineteen. There was no significant difference within any age group in endurance performance between the exercise-neversmokers and exercise-smokers.

Whereas the performance levels of all exercise-smokers in the 10KMR did not improve as a whole, there was an observable increase in the level of performance of the seventeen-year-old exercise-neversmokers in this race when compared to their records at age sixteen. There were significant differences in the 10KMR performance levels between the seventeen or eighteen-year-old nonexercise-neversmokers and nonexercise-smokers (unpaired t-test p<0.05.)

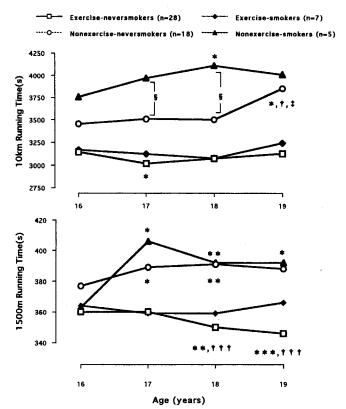


Fig. 1 Changes in the mean values of 10km running time (Top) and 1500m running time (Bottom) during a four-year period among 16-to 19-year-old males grouped by exercise habit and smoking habit.

*p<0.05, **p<0.01, ***p<0.001:Significantly different from the values of 16 years old.

† p<0.05, ††† p<0.001:Significantly different from the values of 17 years old.

‡ p<0.05: Significantly different from the values of 18 years old.

§ p<0.05; Unpaired t-test.

Correlation Between Age of Smoking Initiation and Endurance Performance Levels

Figure 2 shows the longitudinal effects that the age of smoking initiation had on performance levels of the 1500MR and 10KMR. In general, there was no clear relationship between the endurance performance level and the age of smoking initiation. However, it should be noted that there was a

significant increase in the performance levels of the nineteenyear-old non-smokers in the 1500MR when compared to their records at age seventeen (p<0.001).

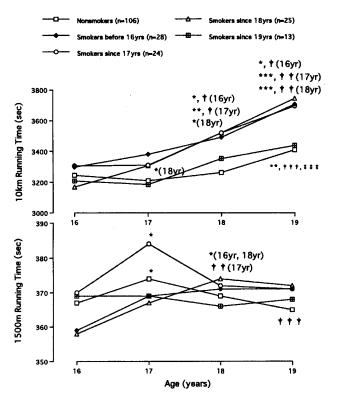


Fig. 2. Changes in the mean values of 10km running time (Top) and 1500m running time (Bottom) during a four-year period among 16- to 19-year-old males group by the age of smoking initiation.

*<0.05, **p<0.01, ***p<0.001:Significantly different from the values of 16 years old.

† p<0.05, † † p<0.01, † † † p<0.001:Significantly different from the values of 17 years old.

‡ p<0.05, ‡ ‡ p<0.01: Significantly different from values of 18 years old.

Discussion

The physical endurance levels of teenagers have recently been found not to be improving as the age of the teenagers increases⁶⁾. Although the absolute VO₂ max (mL·min⁻¹) and VO₂ (mL·kg⁻¹·min⁻¹) show little or no change among fourteen- to eighteen-year-old males^{11,12)}, according to the recommendations of the American College of Sports Medicine¹³⁾, if male teenagers are involved in any form of exercise activities, their endurance performance levels should increase with an increase in age. We suspect that endurance levels among teenagers are diminishing rather than increasing because of the detrimental effects of smoking on the bodies of teenage smokers.

The results of this study show that, in the 1500MR, the performance levels of the exercise-neversmokers did improve as the subjects grew older, whereas the exercise-smokers, over the same period of aging, were able only to maintain, and not improve, their performance levels. These findings, based on longitudinal data, support the hypothesis that young smokers would obtain less benefits from physical training than non-smokers?

The claim that smoking has a deleterious effect on endurance

performance levels is further supported by the results of a crosssectional analysis of the data. Little information related to the effects of the smoking on the long-term endurance performance levels as 10KMR among teenagers was available¹⁴. In the 10KMR run by the eighteen and nineteen-year-olds, there were significant differences in the performance levels between the non-smokers and smokers. The results of the two-way ANOVA show that smoking negatively and independently impacted on the eighteen and nineteen-year-olds' performance in the 10KMR. These results suggest that we need to assess endurance performance levels among teenagers by looking more closely at their smoking habits. We observed no differences in the physical characteristics and exercise habits between the smokers and non-smokers. Therefore, the cause of the observed lack of an increase in the endurance performance levels of young smokers could be associated not with the quantity (such as the mass of muscle or fat¹⁴), but rather with the functional capabilities or the quality of the organ or the tissue, such as the ability to use oxygen¹²⁾. This possibility is supported by several findings. Adams et al. found that smoking induces respiratory impairment in children in secondary school¹⁵. Krumholz et al. also reported that alterations in lung function are present in young cigarette smokers and that some of these alterations have been observed to be quickly reversible within a three-week period after smoking has been stopped¹⁶⁾. Smoking cessation improves the oxygen debt¹⁶⁾. Dressendorfer et al. reported that the level of exercise performance among smokers was lower perhaps because smokers have less breathing capacity or a reduced ventilatory muscle endurance⁴⁾.

A significant finding of the present study was that the reduced levels of endurance performance in non-exercise smokers were revealed in the results of the 10KMR, and that the diminished performance levels of the exercise smokers appeared in the results of the 1500MR. The effects of smoking on endurance performance levels most predominantly manifest themselves in exercise activities that have an intensity level below the anaerobic threshold (AT), a phenomenon which, in the case of these findings, expressed itself in the situation of non-exercise smokers^{17,18)}. In a similar manner, the effects of smoking on exercise-smokers in this study manifested themselves in an intensity of exercise exertion above the AT. We speculate that the 1500MR demands an oxygen debt of exercisers, while the 10KMR does not require this debt of non-exercisers. We observed no significant difference in lean body muscle, which is termed as limiting factor of oxygen debt, between the groups. In fact, we found that the lean body muscle values of the exercisesmokers, nonexercise-smokers, and nonexercise-nonsmokers were essentially the same. Chevalier et al. showed that carbon monoxide has an effect on oxygen debt accumulation, and this consequently raises the possibility that carbon monoxide could alter one's ability to do aerobic work. An individual would therefore require more anaerobic work in order to experience a subsequent increase in oxygen debt accumulation¹⁹⁾. The poor performance of the nonexercise-smokers in the results of the 1500MR may be attributable to the accumulation of carbon monoxide from smoking. On the other hand, the decreased endurance performance of the nonexercise-smokers in the 10KMR might be due to a diminished breathing capacity, such as in the case of a smaller breathing airway, or to reduced ventilatory muscle endurance4).

Based on the present findings, we did not observe a clear

negative relationship between the age of smoking initiation and endurance performance levels. Dressendorfer et al. found that heavy smoking can reduce aerobic exercise tolerance even before the pathological effects of heavy smoking are clinically detectable⁴). Therefore, taking the different factors of smoking into consideration, further studies to determine how the age of smoking initiation affects endurance performance will be essential.

In summary, we investigated the impact of smoking on the performances of sixteen- to nineteen-year-old males in the running of a 1500 meter race and a 10 kilometer race. Significant differences between the 10KMR performance levels of eighteen or nineteen-year-old non-smokers and smokers revealed that smoking has a detrimental effect on a teenage body's capacity to perform physical activity. This state was specifically revealed in the reduced endurance performance of non-exercise smokers in the 10KMR, and the diminished performance levels in exercise-smokers in the 1500MR. These results suggest that in order to fully understand the factors responsible for the declining level of physical fitness among teenagers, attention must be paid to their smoking habits.

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